Hospital organisation, management, and structure for prevention of health-care-associated infection: a systematic review and expert consensus

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Despite control efforts, the burden of health-care-associated infections in Europe is high and leads to around 37 000 deaths each year. We did a systematic review to identify crucial elements for the organisation of effective infection-prevention programmes in hospitals and key components for implementation of monitoring. 92 studies published from 1996 to 2012 were assessed and ten key components identified: organisation of infection control at the hospital level; bed occupancy, staffing, workload, and employment of pool or agency nurses; availability of and ease of access to materials and equipment and optimum ergonomics; appropriate use of guidelines; education and training; auditing; surveillance and feedback; multimodal and multidisciplinary prevention programmes that include behavioural change; engagement of champions; and positive organisational culture. These components comprise manageable and widely applicable ways to reduce health-care-associated infections and improve patients' safety.

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Introduction

Health-care-associated infections (HAIs) affect millions of patients worldwide every year.[1,2] In the European Union (EU) alone, the estimated number of HAIs is 4 544 100 annually, leading directly to around 37 000 deaths and 16 million extra days of hospital stay.[3] Several evidence-based practice guidelines have been published in the past decade[4–12] but, despite evidence suggesting that good practice strategies are sufficient, hospitals struggle to comply.[13–17] The systematic review and evidence-based guidance on organisation of hospital infection control programmes (SIGHT) was funded by the European Centre for Disease Prevention and Control. Our objective was to provide evidence-based guidance on the organisation of infection-control programmes in hospitals. In particular, the review aimed to identify the most effective and generally applicable elements of acute-care infection-control and prevention programmes and to identify indicators of structure and process for monitoring. In contrast to more procedure-focused recommendations, we address mainly management and organisational features.

Methods

The systematic review was done according to the PRISMA guidelines[18] at three participating institutions (University of Geneva Hospitals, Geneva, Switzerland; Imperial College London, London, UK; and University Hospital of Freiburg, Freiburg, Germany). We separated this project into two work packages: first, a systematic review to identify elements for the organisation of infection-prevention programmes in hospitals and, second, the selection from these of key components, assessment of their implementation and EU-wide applicability, and allocation of process and structure indicators (figure 1).

Search strategy and selection criteria

The search was stratified by five dimensions that we addressed separately: organisational and structural arrangements to implement infection-control programmes, including access to qualified infection-control professionals and the roles of management and advisory committees; targets and methods of HAI surveillance, outbreak management, and the role of feedback; methods and effectiveness of educating and training health-care workers (HCWs); effectiveness of interventions on behavioural change and quality of care, particularly in the context of multimodal prevention strategies; and overview and effectiveness of local policies and resources for standard and transmission-based isolation precautions (figure 1).

We searched Medline, the Cochrane Controlled Trials Register, Embase, the Outbreak Database, PsychINFO, and the Health Management Information Consortium database for reports published between Jan 1, 1996, and Dec 31, 2012. Any landmark papers we found that were published before 1996 were also included. Studies in English, French, German, Italian, Portuguese, and Spanish were eligible when an English title or abstract was available. Studies were eligible for full-text review if they were done in acute-care settings in the context of infection control and were quantitative studies, such as randomised controlled trials, controlled clinical trials, case-control studies, controlled before-and-after studies, interrupted-time series, non-controlled cohort studies, and non-controlled before-and-after studies, or qualitative studies if they were based on in-depth interviews, questionnaires, surveys, focus groups, and direct observations, irrespective of whether they were empirical or grounded in a recognised theory, or used mixed methods to combine quantitative and qualitative investigations. Reviews, letters, notes, and opinion articles that did not report primary data were excluded. Interventions related to community care, primary care, antibiotic prescribing, or a combination of these, were excluded, as were studies done in long-term care settings. Antibiotic stewardship, cost-effectiveness, and occupational health were not addressed because these

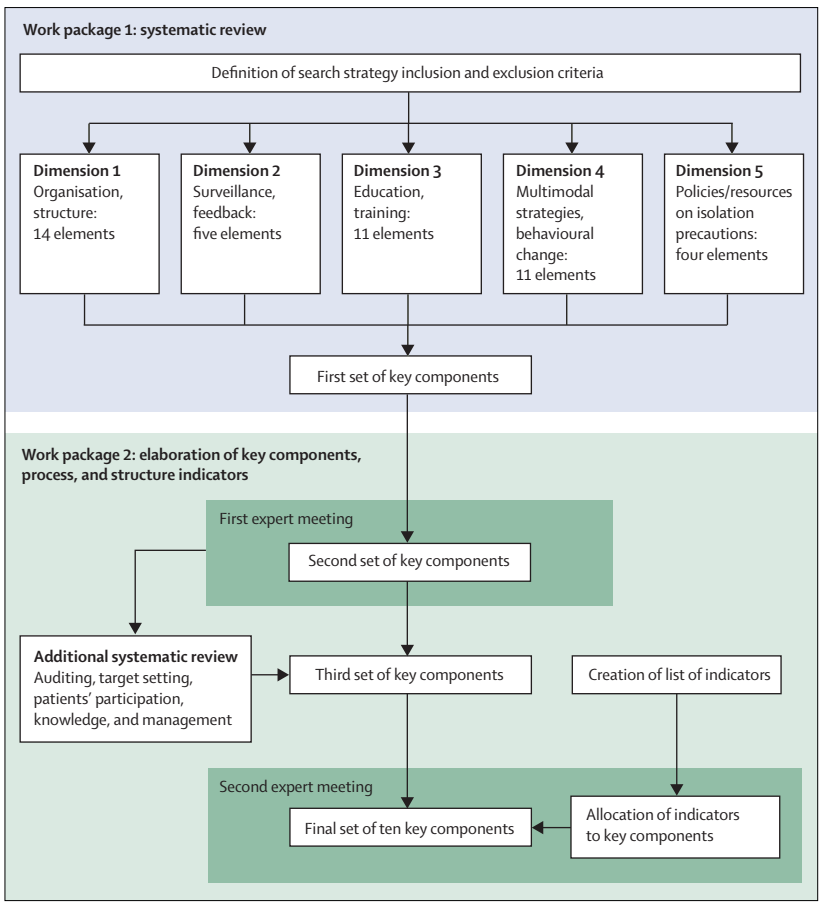

Figure 1: **Outline of the systematic review and component assessment**

topics were elements of other European Centre for Disease Prevention and Control projects at the time of the study. Additional inclusion and exclusion criteria are summarised in the appendix.

See Online for appendix

Initial assessment was done by screening titles and abstracts against the inclusion and exclusion criteria. Reports without abstracts were read in full. 30% of the titles and abstracts and 100% of the full texts were assessed by a second reviewer. Disagreements were resolved by consensus or by a third reviewer if agreement could not be reached. Reference lists of relevant articles were searched to identify further studies. If the full text could not be obtained by any of the participating academic centres or by the European Centre for Disease Prevention and Control, the study was excluded from further analysis. Study origin was stratified by country income, as defined by the World Bank classification.[19]

We used the integrated quality criteria for systematic review of multiple study designs tool[20] to assess the quality of articles. This approach integrates criteria to evaluate quantitative and qualitative studies. The quality of evidence is graded on the basis of an overall score if the studies meet a set of specific criteria that are designed for each study (appendix).[21,22] Quality assessment was done by two reviewers for all studies (WZ, AH , MD, TG, FS, and LC). Disagreements were resolved by consensus and a third reviewer was consulted if agreement could not be reached. Quality of studies was graded as low (1), medium (2), or high (3).

Data extraction

An expert group was established, with independent and author members selected according to their area of expertise (infection control, patients' safety, public health, quality improvement, health policy, organisational theory, psychology, and sociology). Elements emerging from the systematic review were categorised under key components of infection control by the study group and presented to the experts, who checked each one for the validity of classification, assessed EU-wide applicability and ease of implementation, and defined structural and process indicators (figure 1). Evidence was graded as low (1), intermediate (2), or high (3) on the basis of the median value for the studies contributing to the component.

To score implementation and EU-wide applicability, the expert group considered potential barriers. For instance, implementation might be affected by budget and financial constraints, work cultural issues, work ethics, leadership, communication, educational background, personal experience, relative priority in the institution, and hospital-wide applicability. Potential barriers to EU-wide applicability might be a financial crisis, cultural issues, specifics of the health-care system, training opportunities for infection control, national safety programmes, and emigration of specialty professionals. Ease of implementation and EU-wide applicability were graded as low (1), intermediate (2), or high (3). Consensus about grading was reached with the Delphi method.[23]

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

Our search yielded 47 948 titles and abstracts and an additional 131 were added through cross-referencing. 92 articles were eligible for data extraction and analysis (figure 2, table 1, appendix).[15–17,24–112] Most evidence was from high-income countries, with only eight (8·7%) studies being from upper-middle-income or lower-middle-income countries.[28,29,42,58–60,71,107] 41 (44·6 %) studies had been done in Europe.

Ten components were identified as being crucial to effective infection control in hospitals: organisation of infection control at the hospital level; bed occupancy, staffing, workload, and employment of pool or agency

nurses; availability of and easy access to materials and equipment and optimum ergonomics; appropriate use of guidelines; education and training; auditing; surveillance and feedback; multimodal and multidisciplinary prevention programmes that take into account principles of behavioural change; engaging champions in prevention programmes; and the role of a positive organisational culture (table 2).

Organisation of infection control at hospital level

Seven studies included assessment of hospital organisation[17,115–120] and indicated that an effective infection control programme in an acute-care hospital must include nursing staff, a dedicated physician trained in infection control, microbiological support, and data management support. One study provided data on staff-to-bed ratios and indicated a maximum ratio of one nurse per 250 hospital beds.[17] Although this cutoff had been chosen a priori on the basis of previous data,[121–124] the study proved that less favourable ratios were associated with worse reductions in HAI rates.

The quality of the evidence was graded intermediate, but ease of implementation and EU-wide applicability were both rated high because surveys, such as the PROHIBIT survey, have shown that the ratio of infection-control nurses to beds is already established.

The identified structural and process indicators were regular reviews of surveillance, prevention programmes, and the number of outbreaks, and annual audits reviewed against appropriate staffing, goals, and sufficient budget allocation.

Ward occupancy and workload

To ensure that ward occupancy does not exceed the capacity for which it is designed and staffed, the workload of frontline HCWs must be adapted accordingly, and the number of pool or agency nurses and physicians should be kept to a minimum. Transmission of and infection with meticillin-resistant *Staphylococcus aureus* (MRSA) was associated with bed occupancy in five studies,[32,74–76,78,113] and with low staffing and nurse-to-patient ratios in seven studies.[31,35,73,77,81,84,112] Three studies reported that higher numbers of permanent staff HCWs and improved nurse-to-patient ratios reduced HAI.[79,80,82] Inadequate adherence to hand-hygiene protocols was associated with low staffing levels in one study and with high workload in another.[83,100] Long work hours were associated with increased rates of HAIs in one study,[112] and MRSA infections with high workload in another.[73] Pool or agency nurses who worked on different wards as needs required were identified as a potential risk for bloodstream infections, especially catheter-associated bloodstream infections in intensive-care units.[36,72]

The evidence of staffing levels being a risk factor for HAI was graded high and intermediate for bed occupancy, workload, and high ratios of pool or agency nurses. Ease of implementation was rated as intermediate, restricted mostly by budget, lack of specialist nurses, and shortcomings in workforce management. EU-wide applicability was rated intermediate because of economic challenges to national health-care systems.

The identified structural and process indicators were regular assessment of the average bed occupancy at midnight, the number of frontline workers, and the proportion of pool or agency nurses.

Materials, equipment, and ergonomics

Hand-rub dispensers directly in the view of HCWs[24,63] and hand-hygiene facilities at the point of care both improved overall hand hygiene.[55,56,64,125] Limited access to hand-hygiene facilities was a source of frustration to HCWs.[96,97] An easy-to-use pocket hand-rub dispenser attached to scrubs improved hand hygiene among anaesthesiologists.[50] Electronic reminders (pop-up windows) when physicians started to write an order for a patient who fulfilled the criteria for isolation precautions improved the prescribing of these measures.[48] Customised insertion kits for central venous catheters and carts stocked with appropriate materials helped to decrease rates of central-line-associated bloodstream infections.[51,102]

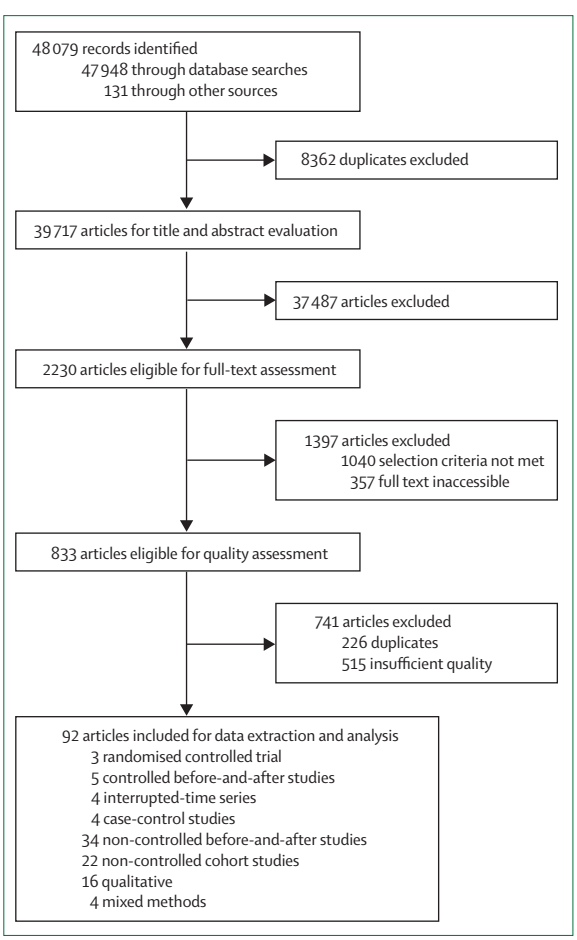

Figure 2: **Systematic review profile**

For the **PROHIBIT survey** see http://www.prohibit.unige.ch

	Study quality grading*	Study design	Income	Infection control topic
Abela and Borg, 2012[85]	2	Non-controlled cohort study	High	Hand hygiene
Alonso-Echanove et al, 2003[72]	3	Non-controlled cohort study	High	CLABSI
Andersen et al, 2009[31]	2	Non-controlled interrupted time-series analysis	High	Health-care-associated infection
Bärwolff et al, 2006[39]	2	Non-controlled before and after study	High	Surgical-site infection
Barsuk et al, 2009[27]	3	Controlled before and after study	High	Bloodstream infection
Birnbach et al, 2010[24]	3	Randomised controlled trial	High	Hand hygiene
Blatnik and Lesnicar, 2006[73]	2	Non-controlled cohort study	High	MRSA
Bouadma et al, 2010[40]	2	Non-controlled before and after study	High	Ventilator-associated pneumonia
Borg, 2003[74]	2	Non-controlled cohort study	High	MRSA
Borg et al, 2008[32]	2	Non-controlled cohort study	High	MRSA
Brandt et al, 2006[41]	2	Non-controlled before and after study	High	Surgical-site infection
Brown et al, 2003[42]	3	Non-controlled before and after study	Upper-middle	Hand hygiene
Charrier et al, 2008[25]	2	Randomised controlled trial	High	Care processes
Cocanour et al, 2006[43]	3	Non-controlled before and after study	High	Ventilator-associated pneumonia
Costers et al, 2012[67]	2	Non-controlled before and after study	High	Hand hygiene
Creamer, 2000[93]	3	Qualitative	High	Peripheral venous catheter care
Creedon, 2006[109]	2	Mixed-methods	High	Hand hygiene
Cunningham et al, 2006[76]	3	Non-controlled cohort study	High	MRSA
Cunningham et al, 2005[113]	2	Non-controlled cohort study	High	MRSA
Damschroder et al, 2009[94]	3	Qualitative	High	CLABSI, ventilator-associated pneumonia
DePalo et al, 2010[33]	2	Non-controlled interrupted time-series analysis	High	CLABSI, ventilator-associated pneumonia
Doron et al, 2011[68]	2	Non-controlled before and after study	High	Hand hygiene
Eggimann et al, 2000[15]	2	Non-controlled cohort study	High	CLABSI
Elder et al, 2008[95]	3	Qualitative	Na	Perception of safety climate
Fridkin et al, 1996[77]	2	Non-controlled cohort study	High	CLABSI
Fuller et al, 2012[26]	3	Randomised controlled trial	High	Hand hygiene
Gastmeier et al, 2005[44]	2	Non-controlled before and after study	High	Surgical-site infection
Gastmeier et al, 2006[45]	2	Non-controlled before and after study	High	Ventilator-associated pneumonia
Gastmeier et al, 2009[46]	2	Non-controlled before and after study	High	Surgical-site infection
Gastmeier et al, 2011[69]	2	Non-controlled before and after study	High	Urinary-tract infection
Geubbels et al, 2006[47]	2	Non-controlled before and after study	High	Surgical-site infection
Grayson et al, 2011[86]	2	Non-controlled cohort study	High	Hand hygiene
Haessler et al, 2012[87]	2	Non-controlled cohort study	High	Hand hygiene
Haley et al, 1985[17]	2	Controlled before and after study	High	Health-care-associated infection
Harris et al, 2000[96]	2	Qualitative	High	Hand hygiene
Henderson et al, 2012[70]	2	Non-controlled before and after study	High	MRSA
Howie and Riley, 2008[78]	2	Non-controlled cohort study	High	MRSA
Hugonnet et al, 2007[79]	3	Non-controlled cohort study	High	Health-care-associated infection
Hugonnet et al, 2007[80]	3	Non-controlled cohort study	High	Ventilator-associated pneumonia
Hugonnet et al, 2007[81]	3	Non-controlled cohort study	High	Health-care-associated infection
Jain et al, 2011[88]	3	Non-controlled cohort study	High	MRSA
Jamal et al, 2012[89]	2	Non-controlled cohort study	High	Hand hygiene
Jang et al, 2010[97]	3	Qualitative	High	Hand hygiene
Joshi et al, 2012[107]	2	Qualitative	Lower-middle	Organisational culture
Kho et al, 2008[48]	2	Non-controlled before and after study	High	Isolation precaution measures
Kilbride et al, 2003[49]	2	Non-controlled before and after study	High	Hand hygiene
Kirkland et al, 2012[90]	2	Non-controlled cohort study	High	Hand hygiene
Koff et al, 2009[50]	2	Non-controlled before and after study	High	Hand hygiene

(Table 1 continues on next page)

	Study quality grading*	Study design	Income	Infection control topic
(Continued from previous page)				
Koll et al, 2008[51]	2	Non-controlled before and after study	High	CLABSI
Larson et al, 2007[52]	2	Non-controlled before and after study	High	Hand hygiene
Lederer et al, 2009[53]	2	Non-controlled before and after study	High	MRSA, hand hygiene
L'Heriteau[54]	2	Non-controlled before and after study	High	CLABSI
Lines, 2006[98]	3	Qualitative	High	MRSA
Mark et al, 2007[82]	3	Non-controlled cohort study	High	Health-care-associated infection
Marra et al, 2010[28]	3	Controlled before and after study	Upper-middle	Hand hygiene
Mathai et al, 2011[71]	2	Non-controlled before and after study	Lower-middle	Hand hygiene
Mayer et al, 2011[34]	3	Controlled cohort study/interrupted time-series analysis	High	Hand hygiene
McLaws et al, 2009[55]	2	Non-controlled before and after study	High	Hand hygiene
McLaws et al, 2009[56]	2	Non-controlled before and after study	High	MRSA
Moongtui et al, 2000[29]	2	Controlled before and after study	Upper-middle	Compliance with universal precautions
Nicol et al, 2009[99]	3	Qualitative	High	Hand hygiene
Nijssen et al, 2003[83]	2	Non-controlled cohort study	High	Hand hygiene
Parand et al, 2011[37]	3	Cross-sectional	High	Health-care worker perception of study effectiveness
Peredo et al, 2010[57]	2	Non-controlled before and after study	High	Bloodstream infection
Petrosillo et al, 2001[35]	2	Case-control	High	Hepatitis C virus infection
Pinto et al, 2011[108]	2	Qualitative	High	Health-care worker perception of study effectiveness
Pittet et al, 2000[16]	2	Non-controlled before and after study	High	Hand hygiene
Pittet et al, 2004[100]	2	Cross-sectional	High	Hand hygiene
Pontivivo et al, 2012[91]	2	Non-controlled cohort study	High	Hand hygiene
Quiros et al, 2004[101]	3	Qualitative	High	Health-care-associated infection
Render et al, 2011[92]	3	Non-controlled cohort study	High	CLABSI
Robert et al, 2001[36]	2	Case-control	High	Bloodstream infection
Rosenthal et al, 2003[58]	2	Non-controlled before and after study	Upper-middle	Hand hygiene
Rosenthal et al, 2004[59]	2	Non-controlled before and after study	Upper-middle	Catheter-associated urinary-tract infection
Rosenthal et al, 2005[60]	2	Non-controlled before and after study	Upper-middle	Hand hygiene
Rubinson et al, 2005[102]	3	Qualitative	High	Adherence to guidelines
Saint et al, 2009[110]	2	Mixed-methods	High	Hand hygiene
Saint et al, 2010[103]	3	Qualitative	High	Successful leadership
Schwab et al, 2007[61]	2	Non-controlled before and after study	High	Bloodstream infection
Sherertz et al, 2000[62]	2	Non-controlled before and after study	High	Catheter-related bloodstream infection
Sinkowitz-Cochran et al, 2012[38]	3	Cross-sectional	High	MRSA
Sinuff et al, 2007[104]	3	Qualitative	High	Guideline implementation
Sladek et al, 2008[105]	3	Qualitative	High	Hand hygiene
Thomas et al, 2009[63]	2	Non-controlled before and after study	High	Hand hygiene
Thomas et al, 205[111]	2	Mixed-methods	High	Hand hygiene
Turnberg et al, 2009[106]	3	Qualitative	High	Respiratory precaution measures
Vicca, 1999[84]	3	Non-controlled cohort study	High	MRSAs
Virtanen et al, 2009[112]	3	Mixed-methods	High	Health-care-associated infection
Whitby and McLaws, 2004[64]	3	Non-controlled before and after study	High	Hand hygiene
Yinnon et al, 2012[30]	2	Controlled before and after study	High	Health-care-associated infection
Zingg et al, 2009[65]	3	Non-controlled before and after study	High	CLABSI
Zuschneid et al, 2007[66]	2	Non-controlled before and after study	High	Ventilator-associated pneumonia

MRSA=meticillin resistant *Staphylococcus aureus*. CLABSI=central-line-associated bloodstream infection. *Graded with the integrated quality criteria for systematic review of multiple study designs tool.

***Table 1*: Studies eligible for data extraction and analysis**

Evidence was graded intermediate and ease of implementation and EU-wide applicability were rated intermediate. Potential financial constraints could interfere with the provision of optimum equipment.

Regular audits, for instance to check the availability of hand rub, soap, and single-use towels, was identified as a process indicator.

Use of guidelines, education, and training

1158 HCWs in 40 hospitals stated that they knew about the update of a national guideline on hand hygiene, yet recommendations had been implemented in less than half of the hospitals visited in a national audit in the USA.[52] Physicians showed low adherence to maximum sterile barrier precautions for insertion of central venous catheters, despite strong recommendations to do so.[102] The introduction of a new guideline as part of a multimodal intervention strategy in settings without previous exposure to standardised protocols helped to improve hand hygiene and reduced rates of catheter-associated urinary-tract infections.[59,60,114] Attitudes towards guidelines were more positive among nurses than physicians and in paediatric intensive-care units than in adult intensive-care units.[101]

Evidence was graded intermediate and ease of implementation and EU-wide applicability were both rated high on the basis of the experts' own experience.

Regular review of accessibility to local guidelines and whether the contents of teaching programmes are based on the most updated documents were identified in the assessment of structural and process indicators.

Team-oriented and task-oriented education and training

Bedside teaching as part of a multimodal intervention,[65] simulation-based training,[27] and hands-on training

	Key component	Indicators	Quality of evidence*	Ease of implementation	EU-wide applicability
1	An effective infection-control programme in an acute-care hospital must include as a minimum standard at least one full-time specifically trained infection-control nurse per up to 250 beds, a dedicated physician trained in infection control, microbiological support, and data management support[17]	Continuous review of surveillance and prevention programmes, outbreaks, and audits; infection-control committee in place, inclusion of infection control on the hospital administration agenda, and defined goals (eg, HAI rates); and appropriate staffing and budget for infection control	2	3	3
2	Ward occupancy must not exceed the capacity for which it is designed and staffed; staffing and workload of frontline HCWs must be adapted to acuity of care, and the number of pool or agency nurses and physicians used kept to a minimum[31,32,35,36,72–84,100,112,113]	Average bed occupancy at midnight, average numbers of frontline workers, and the average proportion of pool or agency professionals	2	2	2
3	Sufficient availability of and easy access to materials and equipment, and optimisation of ergonomics[24,48,50,51,55,56,63,64,97,102]	Availability of alcohol-based hand rub at the point of care and sinks stocked with soap and single-use towels	2	2	2
4	Use of guidelines in combination with practical education and training[52,59,60,101,102,1114]	Adaptation of guidelines to local situation, number of new staff trained with the local guidelines, teaching programmes are based on local guidelines	2	3	3
5	Education and training involves frontline staff and is team and task oriented[27,28,62,65,99,101,105–107,111]	Education and training programmes should be audited and combined with knowledge and competency assessments	3	2	3
6	Organising audits as a standardised (scored) and systematic review of practice with timely feedback[25,29,30,43,49]	Measurement of the number of audits (overall, and stratified by departments/units and topics) for specified time periods	2	2	3
7	Participating in prospective surveillance and offering active feedback, preferably as part of a network[39,41,44–47,54,58,61,66,69,108]	Participation in nationals and international surveillance initiatives, number and type of wards with a surveillance, regular review of the feedback strategy	2	2	2
8	Implementing infection-control programmes following a multimodal strategy, including tools such as bundles and checklists developed by multidisciplinary teams, and taking into account local conditions[15,16,26,28,33,34,40,42,51,53,55–57,65,67,68,70,71,86,88,89–92,93,96,97,99,109,111]	Verification that programmes are multimodal; measurement of process indicators (eg, hand hygiene, care procedures); measurement of outcome indicators (eg, HAI rates, MDRO infections and transmission)	2	3	3
9	Identifying and engaging champions in the promotion of intervention strategies[70,91,92,94,110]	Interviews with frontline staff and infection-control professionals	3	2	2
10	A positive organisational culture by fostering working relationships and communication across units and staff groups[37,38,85,87,95,98,103,104]	Questionnaires about work satisfaction, crisis management, and human resource assessments of absenteeism and HCW turnover	3	2	3

See the appendix for detailed information about the studies and comments on the rating of evidence, ease of implementation and EU-wide applicability. HCW=health-care worker. HAI=health-care-associated infections. MDRO=multidrug-resistant organisms. *Median score is used.

***Table 2*: Key components and indicators identified by the systematic review**

workshops for physicians in training[62] reduced the rates of catheter-related bloodstream infections. Multidisciplinary focus groups were crucial to focusing infection-prevention programmes on the target of interest and contributed to improved adherence to hand-hygiene protocols and reduced rates of HAIs.[28,107,111] Qualitative studies showed that, although formal training is effective,[106] individual experience is perceived to be more important for infection prevention,[99] whereas strategies that used traditional approaches based on logic and reasoning were perceived as less likely to improve hand hygiene.[105]

The evidence for this key component was graded high, but ease of implementation was rated intermediate because of potential barriers, such as financial constraints or lack of teaching experience. The expert group emphasised that preparation of a multimodal and multidisciplinary strategy that involves HCWs at all levels requires leadership and good communication. EU-wide applicability was rated high.

Education and training programmes should be audited against predefined checklists that are revised over time to take into account local barriers and behaviour. Education and training should be combined with knowledge tests, competency assessments, or both.

Standardisation of audits

Auditing and personal feedback improves predefined process indicators for catheter insertion.[25] An audit of daily adherence to a bundled strategy to prevent ventilator-associated pneumonia and provision of weekly feedback on pneumonia rates led to reduced numbers of cases of ventilation-associated pneumonia.[43] Cases of bacteraemia caused by coagulase-negative staphylococci were reduced by internal audits on hand hygiene and catheter-hub care in neonates.[49] Audits in the form of assessments by peers and anonymous feedback effectively improved universal precaution measures,[29] and use of a comprehensive checklist covering a wide range of care practices reduced prevalence of all-cause HAIs by 7%.[30]

Evidence was graded intermediate and ease of implementation was rated intermediate, mainly because of potential financial constraints, limited human resources, and lack of leadership and communication. EU-wide applicability was rated high.

Identified structure and process indicators were measurement of the number of audits done and regular assessment of validity of checklists against local and national guidelines.

Prospective surveillance, feedback, and networks

Participation in the German Hospital Infection Surveillance System (KISS) was associated with decreased rates of HAIs,[39,41,44–46,61,66,69] central-line-associated bloodstream infections,[45,46] ventilator-associated pneumonia,[45,66] urinary-tract infections,[69] and surgical-site infections.[39,41,44,45] Hospitals within the Dutch surveillance network, PREZIES, showed reduced rates of HAIs in years 4 and 5 of participation.[47] The 35 intensive-care units of the French ReAct network had reductions in catheter-related bloodstream infections over 5 years.[54] One qualitative study explored the rationale related to the importance of surveillance and feedback to stakeholders, and found they were very influential in the implementation of an infection-control programme targeting ventilator-associated pneumonia.[108]

The evidence was graded intermediate, and ease of implementation and EU-wide applicability were rated intermediate. Potential barriers to implementation were lack of leadership, restricted human resources for surveillance, and infection control being a low priority. EU-wide applicability was limited because not every country has an established surveillance network.

Regular measurement and assessment of the number and type of wards with established surveillance, including the strategy of providing feedback to HCWs, were identified as process indicators. Addition of participation in national and international surveillance initiatives to the hospital administration agenda was also suggested.

Development of multimodal strategies and tools

20 studies showed that multimodal strategies were helpful to improve hand hygiene.[16,26,28,34,42,53,55,56,60,67,68,70,71,86,89–91,99,109,111] Some programmes actively included opinion leaders and champions.[42,70,109] Two studies used the idea of positive reinforcement: in one HCWs were given chocolate bars or sweets when found to be correctly adhering to hand-hygiene protocols[34] and in another the principles of product marketing were applied to encourage HCWs to choose their own intervention from a range of tools.[53] Several factors were identified as affecting hand hygiene, such as accessibility to hand rub, role models, personal sense of responsibility, and emotional involvement.[99]

Eight studies investigated the role and effectiveness of multimodal strategies in reducing catheter-related and central-line-associated bloodstream infection. Seven were quantitative intensive-care studies[15,33,51,57,65,70,92] and one was a qualitative study reporting factors of behavioural change in the context of peripheral venous lines.[93] All intervention studies used a multimodal approach in which bundles or comprehensive procedures were defined and promoted at various levels. Three studies focused primarily on catheter insertion,[33,51,57] one addressed catheter insertion and care,[15] and one focused on catheter care.[65] All seven quantitative studies showed improvement in central-line-associated bloodstream infections. Four studies also provided data about process indicators.[33,65,70,92]

Two studies addressed ventilator-associated pneumonia and showed that multimodal prevention strategies are successful if the programme is developed by a multidisciplinary task force, processes are closely monitored,[40] and a well structured business plan is used to engage all relevant stakeholders.[70]

Numbers of MRSA infections were reduced by use of a strategy bundle based on the principles of positive

deviance to make infection control the responsibility of every stakeholder.[88]

Although the evidence was graded intermediate, ease of implementation and EU-wide applicability were rated high because the wide variety of effective strategies leaves room for local adaptation.

Identified structural indicators were that prevention programmes should be reviewed regularly against predefined checklists that take into account multimodality, local barriers, and aspects of behavioural change. An important process indicator was measurement of activities, such as adherence to hand-hygiene protocols or performance of medical procedures (eg, catheter insertion and care, care of ventilated patients, and placement of urinary catheters). Outcome indicators, such as catheter-associated urinary-tract infection, central-line-associated bloodstream infection, HAI, and ventilator-associated pneumonia, should also be measured.

Identification and engagement of strategy champions

In four studies champions had been engaged as part of a comprehensive and multimodal intervention strategy.[70,91,92,110] One well placed champion was helpful to implement a new technology, but more than one champion was needed when improvements required behavioural change.[94]

The evidence for this key component was graded high, but ease of implementation was rated as intermediate because unfavourable work cultures and lack of leadership might complicate the work of a champion, and suitable individuals could be difficult to identify in a hospital. EU-wide applicability was also rated as intermediate because local culture might interfere with the concept of allowing a champion room for action.

Prevention programmes that describe strategies about how frontline workers can be incorporated in the implementation process and inclusion of champions' names in the agenda of intervention progress meetings were identified as structure and process indicators.

Creating a positive organisational culture

Receiving training and instructional feedback from supervisors and management support for implementing safe work practices are perceived by HCWs to improve adherence to recommended care practices.[106] Adherence to guidelines is affected by knowledge, beliefs, motivation, and professional responsibility.[97] Inconsistency between managers' verbal and written commitments and their daily support of patients' safety issues has a negative effect.[95] Successful leaders are solution oriented and focus on cultivating a culture of clinical excellence.[103] Lack of management support provokes the perception of non-control in situations of high workload.[98] Communication between professional groups can be a barrier to or a facilitator of adherence to best practice.[104] Staff engagement, situations perceived as overwhelming or stressful and chaotic, and hospital leadership are associated with knowledge, attitudes, and self-reported practices of MRSA prevention.[38] Education and leadership engagement improve hand hygiene,[85] and peer pressure and role models are also important.[87] The success of intervention programmes is perceived differently by different professional groups, which should be taken into account in the design of infection-control initiatives.[37]

The evidence for the effects of a positive organisational culture was graded high. Ease of implementation was rated intermediate because work culture is difficult to change, particularly lack of leadership. EU-wide applicability, however, was rated high because barriers are mainly related to an individual organisation, and good examples of positive organisational cultures to draw from can be found in many places.

The expert group found that organisational culture can be measured at an individual level by work satisfaction questionnaires, at a ward or department level by turnover and absenteeism among HCWs, and at an institutional level by assessment of the response to stress or crisis management.

Discussion

This broad systematic review identified a range of structural, organisational, and management components that are crucial to effective implementation of infection-control programmes in hospitals. Additionally, these components were put into a user's perspective by providing context about implementation and EU-wide applicability.

The formal proportion of one infection-control nurse per 250 hospital beds was established more than 30 years ago.[17] However, hospital settings have changed, and expert consensus now suggests that this rate should be around one nurse per 100 beds in acute care,[114,118] and one per 150–250 beds in long-term care.[114,118] Our review shows that infection prevention does not rely solely on a functional infection-control team, but also depends on hospital organisation, bed occupancy, staffing, and workload.[31,32,35,36,72–84,100,112] This message is crucial at a time when HCW posts are being cut. Sufficient availability and easy access to materials and optimised ergonomics improve best-practice performance.[24,48,50,51,55,56,63,64,96,97,102] Unfortunately, these features are not always respected, and a lack of professionals specialised in medical ergonomics could be having a negative effect on care of patients.

Dissemination of guidelines alone does not change behaviour.[52,102] Rather, they should be introduced in the form of educational and practical, evidence-based training.[59,60,114] Studies of education and training suggest that education should be team and task oriented and problem based, and are most effective when they include workshops, bedside teaching, and simulation-based training.[27,62,126] Multidisciplinary focus groups should be set up to aid adjustment of training programmes to suit local

conditions.[65,125] Importantly, education should target specific socialisation processes and address barriers to behavioural change in all professional groups;[101,106] isolated lectures, when unaccompanied by other tools and leadership engagement, are ineffective.[127,128] High-quality auditing and timely feedback also help with the implementation of infection-prevention programmes.[25,43,49] Feedback is an essential component of surveillance programmes to raise awareness of HCWs about issues that need to be addressed, but also to promote an element of competition between hospitals.[129] Almost any process can be audited.

We highlight the importance of multimodal and multidisciplinary strategies for education and training. Additionally, HCWs from multiple levels and work categories should be integrated in the preparation and implementation of intervention programmes. Every study of sufficient quality used a unique intervention strategy and the study settings were generally different and, therefore, the proportion of single components that had an effect on outcome success could not be determined. Nevertheless, the findings all point towards a comprehensive approach that includes adaptation and the use of a broad range of actions to overcome local barriers in the implementation process. An effective strategy needs to focus on individuals in the work situation and to address environmental, organisational, and individual barriers to adherence. Intervention programmes must have a strong behavioural component aimed at removing barriers, stimulating positive attitudes, and helping HCWs to manage workload, without compromising adherence and quality. They also need strong leadership and the involvement of staff at all levels.

Institutional leaders can make a difference, and leadership should be part of their professional responsibility. Educating senior executives about clinical issues and safety hazards and organising executive safety rounds on the wards have been proposed as means to engage them in patients' safety and enlist their support for infection prevention and control.[130] A positive organisational culture can only emerge through the genuine interest of leaders in the wellbeing of their staff and when the right people are in place. Inconsistencies between a manager's verbal and written commitments and what they practise are negatively perceived by HCWs and might work against the idea of showing support to frontline workers.[95] Whether the organsational culture is positive or negative depends on the perception of HCWs,[131] and the success of intervention programmes is perceived differently by different professional groups.[37] We identified the role of champions as a crucial component of effective infection control.[94,110] Champions can work around organisational barriers to change the work environment and thus shape organisational change due to their genuine enthusiasm and engagement. This component, therefore, is judged to stand alone. Champions, however, can be neither appointed nor mandated. Rather, they must be identified and given the support to act as such.

This study has limitations. First, we used the integrated quality criteria for systematic review of multiple study designs tool to assess study quality. This tool is not yet widely established, although it has been used already in several published systematic reviews.[20–22] It seemed to allow more data to be exposed than the more usual grading approaches because of the broader scope of studies eligible for inclusion, especially qualitative studies.

Second, although the three participating institutions and the European Centre for Disease Prevention and Control had access to a large number of journals through their respective libraries, many articles could not be accessed as the full text. This restriction was a result of the inclusive search terms and the aim to look for qualitative research in nursing journals. For the study update, we purchased all non-accessible manuscripts identified for dimensions one and three (organisational and structural arrangements to implement infection-control programmes, including access to qualified infection-control professionals and the roles of management and advisory committees, and methods and effectiveness of educating and training HCWs) to assess the full text. No further studies of sufficient quality were identified and, therefore, we are confident that the systematic review missed very few, if any, relevant high-quality studies.

Third, studies were only eligible if they had been published by Dec 31, 2012 (including electronic prepublication). To obtain an idea about the later evidence base we applied the SIGHT search terms to PubMed to identify studies published in 2013. We retrieved 4036 titles and abstracts, of which 65 addressed the ten key components and would have been potentially eligible for inclusion in this systematic review (appendix). Of these studies, 56 were about using multimodal strategies to improve hand hygiene or prevent HAIs, such as central-line-associated bloodstream infections, catheter-associated urinary-tract infections, or ventilator-associated pneumonia. Almost all clinical settings were represented, with an increasing number of studies being done in non-intensive-care units or hospital wide. Many reports mentioned the role of multidisciplinary teams for preparation and implementation of infection-control interventions. Eight studies gave detailed information about the education strategy, addressed the benefit of clinical audits (three), reported success by participating in a surveillance strategy (two), and discussed staffing and ergonomics (one). Nine studies provided information about leadership and organisational culture. The findings suggest that the SIGHT key components are valid and that these themes are likely to be addressed in an increasing number of future studies.

Search strategy and selection criteria

These are described in detail in the Methods section.

SIGHT aimed to identify the most effective and generally applicable elements of infection prevention, and the strength of this project is that the studies forming the evidence base represent a rigorous selection from hundreds of papers to avoid those with limitations and methodological concerns. In this respect the integrated quality criteria for systematic review of multiple study designs approach was helpful because it consistently identified studies of low quality and with incomplete reporting. In view of the number of publications and the broad dimensions addressed by SIGHT, the small evidence base may seem surprising, but we believe it shows that further good quality studies with accurate reporting are needed to improve the quality of evidence for recommendations.

All key components are important and, although numbered for convenience, SIGHT does not prioritise any over another. Elements such as establishing infection control, providing functional equipment, or hiring more HCWs are more tangible than identifying champions or providing a positive organisational culture. Multimodality in the execution of prevention programmes and multidisciplinary preparation of these, team-oriented and task-oriented training, appropriate use of guidelines, and auditing can be applied in more sociocultural and economic backgrounds than sufficient availability of materials or participating in a surveillance network, because they offer room for adaptation. Individual hospitals should be encouraged to establish the key components that make sense in terms of the specific needs and resources identified through self-assessment.

Conclusions

Infection prevention and control is a priority for patients' safety and should involve HCWs at all levels and be part of the hospital organisation as a whole.[132] Staffing must be adequate to meet task requirements without leading to excessive workload. For prevention purposes, hospital infection-control programmes need to translate the key components into workable documents and programmes that take the local context into account. Programmes should be planned by multidisciplinary groups, take into account local guidelines, follow a multimodal intervention strategy that emphasises hands-on training, and be regularly assessed, and adjusted if necessary. Further research and accurate study reporting are needed to improve the quality of evidence, especially in countries with lower-middle and low incomes.

Contributors

WZ, BA, and DP wrote the grant application. WZ, AH, MD, FS, BA, A-PM, and DP contributed to the concept and design of the study. WZ, AH, MD, TG, FS, LC, and BA collected and interpreted the data. AH provided the integrated quality criteria for systematic review of multiple study designs tool for study evaluation. WZ wrote the first draft of the manuscript, and all authors reviewed and contributed to subsequent drafts and approved the final version for publication.

Declaration of interests

We declare no competing interests.

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